

## Observations of possible symbiotic star V335 Vul

Petr Sobotka, Ondřej Pejcha

*MEDUZA, N. Copernicus Observatory and planetarium in Brno, Kraví hora 2, 616 00 Brno, Czech Republic*

Ladislav Šmelcer

*MEDUZA, Valašské Meziříčí Observatory, Vsetínská 78, 757 01 Valašské Meziříčí, Czech Republic*

Pavel Marek

*MEDUZA, Škroupova 957, 500 02 Hradec Králové, Czech Republic*

**Abstract.** We present visual and CCD VRI observations of a suspected symbiotic binary V335 Vul. Long term photometry suggests usual Mira or SRa pulsations. High speed  $V$  band CCD photometry didn't reveal anything unusual above 0.02 mag.

### 1. Introduction

V335 Vul = (AS 356 = GSC 02128.00676 = LD 120 = IRAS 19211+2421) was first noticed by Merrill and Burwell (1950) as a star with an apparent H- $\alpha$  emission. Nassau and Blanco (1957) resolved V335 Vul as a cool carbon star. This was confirmed by Stephenson (1971).

The star was found to be variable by Collins (1991) on photographic plates with maximum magnitude at 10.1 mag and minimum under the limiting magnitude of the plates at 12.7 mag. Collins also determined the type of variability to be SR with ephemeris like  $\text{Max} = 2447767 + 336 \times E$ . This information caused the appearance of the star in the 71<sup>st</sup> name-list of variable stars (Kazarovets et al. 1993). The independent discovery of variability came from Dahlmark (1993). From his photographic measurements between 1985 and 1992, he could derive following ephemeris:  $2446740 + 342.0 \times E$ . He also noted that the period of light changes was stable during 1967 and 1992 and found  $B - V = 3.3$  mag. The type of variability was determined to be on the edge between Mira and SRa.

Munari, Tomov and Rejkuba (1999) argued (using echelle spectra) that V335 Vul is probably a symbiotic binary. Munari et al. (1999) discovered an apparent outburst of V335 Vul with significant change of colour index  $B - V$  from 5.01 to 3.06 mag. Belczynski et al. (2000) attributed V335 Vul to stars suspected from symbiotic nature. Munari and Jurdana-Sepic (2002) examined Asiago photographic plates for data on V335 Vul, but insufficient coverage of two years by only 26 points in  $B$  or  $V$  filters did not permit detailed analysis.

## 2. Observations

Since the spring of 2000, MEDUZA group has been conducting extensive observing campaign on V335 Vul. This include long-term VRI CCD measurements from N. Copernicus Observatory and planetarium in Brno by P. Sobotka and O. Pejcha, long-term  $V$  band CCD measurements conducted by L. Šmelcer at Valašské Meziříčí Observatory, high-speed  $V$  band CCD photometry on three nights made at Hradec Králové Observatory by P. Marek, and visual observations carried out by amateur astronomers in the Czech and Slovak Republics, mostly by P. A. Dubovský, L. Brát and O. Pejcha. As a result of the campaign, 1086 CCD long-term measurements in all filters and 192 visual estimates have been made.

CCD observations from Brno and Hradec Králové observatories were reduced by the means of Munidos software (Hroch, Novák and Král, 2002); observations from Valašské Meziříčí were reduced using CCDOPS software bundled with SBIG CCD cameras. CCD data from Brno Observatory have been transformed to the standard Johnson-Cousins system, CCD data from Valašské Meziříčí Observatory have not. Systematical error of the transformations should not exceed 0.1 mag level.

All observations were made with respect to the precisely measured comparison stars of Henden and Munari (2000). The only exceptions are the two brightest stars used only for visual observations - their magnitudes were taken from the Tycho and Tycho-2 catalogues.

Before doing any analysis, visual observations have been averaged by moving averages (with 50 days width and 1 day step) using MedPrum procedure written by M. Haltuf. For plot clarity, weighted averages of CCD observations made on the same night with the same filter and by one observer were done. Times of minima and maxima were derived by Kwee and Van Woerden method using program AVE by R. Barberá.

## 3. Results

High-speed photometry did not reveal anything unusual above 0.02 mag level. This is not unexpected - amplitudes of flickering in the  $V$  band tend to be very small among symbiotic binaries. This is not the best way how to prove or disprove the symbiotic nature of the star.

In Figure 1 we present averaged VRI light curves of V335 Vul as obtained from the multi-colour observations by P. Sobotka and O. Pejcha (and also L. Šmelcer in the case of  $V$  filter). All our observations suggest ordinary Mira or SRa type variations with slightly different depths of minima. The observed maximum is symmetric in all passbands. Maximum and minimum brightness vary in time, see Table 1.

We conclude that the outburst announced by Munari et al. (1999) is identical with ordinary Mira-like pulsations. If V335 Vul is a symbiotic binary, it is similar e.g. to R Aqr.

In Figure 2 we present changes of  $R - I$  and  $V - R$  colour indices compared with  $V$  band light changes. As expected, the star is redder near minimum light. Changes of colour indices are presented in Table 2.

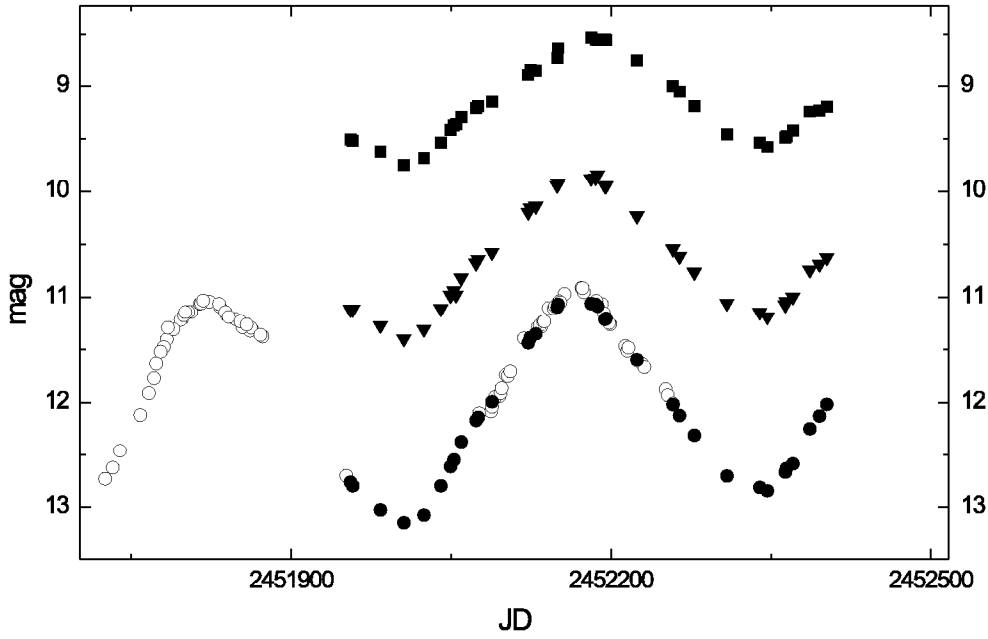


Figure 1. CCD observations of V335 Vul. Squares represents CCD+I, triangles represents CCD+R and circles represents CCD+V data, respectively. Open circles represents data from Valašské Meziříčí and filled circles represents data from Brno.

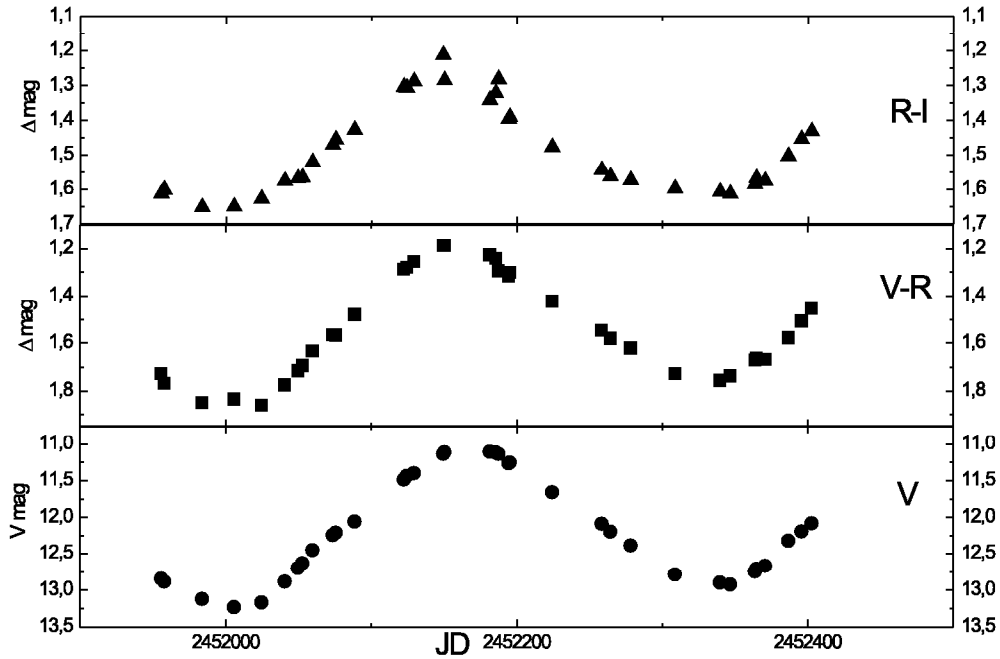


Figure 2. CCD observations of V335 Vul. Changes of  $R-I$  and  $V-R$  colour indices compared with  $V$  band light changes are presented.

Table 1. Magnitudes of minima and maxima and average amplitudes in filters.

filter	max <sub>1</sub>	min <sub>1</sub>	max <sub>2</sub>	min <sub>2</sub>	$\Delta mag$
<i>V</i>	11.23	13.23	11.04	12.92	1.94
<i>R</i>		11.40	9.82	11.19	1.48
<i>I</i>		9.75	8.52	9.58	1.15

Table 2. Magnitudes of minima and maxima of colour indices.

index	min <sub>1</sub>	max	min <sub>2</sub>	$\Delta mag$
<i>V - R</i>	1.86	1.19	1.75	0.62
<i>R - I</i>	1.65	1.25	1.61	0.38

Times of maximum depends on wavelength:  $V = 2452169 \pm 1$ ,  $R = 2452173 \pm 1$  and  $I = 2452183 \pm 1$ . Maxima of *R* and *I* band curves occurred 4 and 14 days after the *V* band maximum, respectively.

Observed *V* band maxima occurred at JD  $2451822.2 \pm 0.5$  and  $2452169 \pm 1$  leading to the period of approx. 347 days, which is similar to previous works.

All visual observations as well as the chart with sequence can be downloaded via MEDUZA webpage at <http://www.meduza.info>.

**Acknowledgments.** We are thankful to all visual and CCD observers who dedicated their time to V335 Vul and L. Král and M. Haltuf for software support. This research has made use of NASA's Astrophysics Data System.

## References

- Belczynski, K., et al. 2000, *A&A*, 146, 407  
 Collins, M., 1991, *The Astronomer*, 28, 182  
 Dahlmack, L., 1993, *IBVS* 3855  
 Henden, A., Munari, U., 2000, *A&A*, 143, 343  
 Hroch, F., Novák, R., & Král, L., 2002, <http://munipack.astronomy.cz>  
 Kazarovets, E. V., Samus, N. N., & Goranskij, V. P., 1993, *IBVS* 3840  
 Merrill, P. W., Burwell, C. G., 1950, *ApJ*, 112, 72  
 Munari, U., Jurdana-Sepic, R., 2002, [www.arxiv.org/astro-ph/0202118](http://www.arxiv.org/astro-ph/0202118)  
 Munari, U., Tomov, T., Moro, D., Henden, A., 1999, *IAUC* 7329  
 Munari, U., Tomov, T., Rejkuba, M., 1999, *IBVS* 4668  
 Nassau, J. J., Blanco, V. M., 1957, *ApJ*, 125, 195  
 Stephenson, C. B., 1971, *PWSO*, 1, 4